



Description

GLOBAL ELECTRONIC TRADING SYSTEM

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Related Applications

This application is related to and claims priority upon U.S. provisional patent application serial number 60/249,796 filed November 17, 2000 and U.S. provisional patent application serial number 60/288,310 filed May 2, 2001, which two provisional patent applications are hereby incorporated by reference in their entireties into the present patent application.

Technical Field

This invention pertains to the field of global electronic trading of commodities and financial instruments.

Background Art

Wright, Ben, "Unlocking the C2C forex riddle", euromoney.com, July 25, 2001, U.K., provides a general discussion of some of the business aspects of the present invention.

Morris, Jennifer, "Forex goes into future shock", Euromoney, October 2001, gives a general description of several computerized foreign exchange platforms, including one described in the present patent application.

1 Ahuja, R.K., Magnanti, T.L., and Orlin, J.B., Network
2 Flows; Theory, Algorithms, and Applications, Chapters 7 and 9
3 (Prentice-Hall, Inc. 1993), U.S.A., sets forth some algorithms
4 that may be useful in implementing the present invention.

5 U.S. patent 5,375,055 discloses a relatively simple
6 trading system that is capable of implementing only single-hop
7 trades. On the other hand, the present invention can
8 accommodate multi-hop trades. Further, in U.S. patent
9 5,375,055, the user is given information that suggests to him
10 that he can take a trade when he may not have enough credit to
11 take the whole trade. In the present invention, on the other
12 hand, if only part of a trade can be executed, that information
13 is given to the user; the user knows that he has enough credit
14 to execute at least the best bid and best offer that are
15 displayed on his computer.

16
17 An even simpler trading system is disclosed in European
18 patent application 0 411 748 A2 and in granted European patents
19 0 399 850 B1 and 0 407 026 B1, all three of which are assigned
20 to Reuters Limited. These Reuters documents describe a system
21 in which information concerning a potential trade is displayed
22 even if the user can't execute it at all. In the present
23 invention, such a potential trade would not be displayed at
24 all. Furthermore, the only credit limits that can be
25 accommodated in the Reuters system are volume limits for the
26 purposes of limiting settlement risk. In the present
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1 invention, any agent may set credit limits in multiple ways so
2 as to limit not only settlement risk (measured both by
3 individual instrument volumes and by notional absolute values)
4 but also exposure risk. Furthermore, the Reuters keystations
5 require a human operator. In the present invention, on the
6 other hand, an API (application programming interface) enables
7 any participant to develop programs which partially or fully
8 automate the trading process.

9 Disclosure of Invention

10 Methods, systems, and computer readable media for
11 facilitating trading two items (L,Q) from the group of items
12 comprising commodities and financial instruments. At least two
13 agents (2) want to trade some instrument L at some price quoted
14 in terms of another instrument Q. The exchange of L and Q is
15 itself a financial instrument, which is referred to as a traded
16 instrument. A trading channel (3) between the two agents (2)
17 allows for the execution of trades. Associated with each
18 channel (3) are trading limits configured by the two agents (2)
19 in order to limit risk. A central computer (1) coupled to the
20 two agents (2) is adapted to convey to each agent (2) current
21 tradable prices and available volumes for the exchange of L for
22 Q and for the exchange of Q for L, taking into account the
23 channel (3) trading limits. The central computer (1)
24 facilitates trades that occur across a single trading channel
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1 (3) and trades that require the utilization of multiple trading
2 channels (3).

3
4 Brief Description of the Drawings

5 These and other more detailed and specific objects and
6 features of the present invention are more fully disclosed in
7 the following specification, reference being had to the
8 accompanying drawings, in which:

9 Figure 1 is a block diagram illustrating a "type zero"
10 trading system embodiment of the present invention.

11 Figure 2 is a block diagram illustrating a "type 1"
12 trading system embodiment of the present invention.

13 ~~There is no Figure 3.~~

14
15 Figure 3 is a block diagram illustrating a "type 2"
16 trading system embodiment of the present invention.

17 Figure 4 is a block diagram illustrating a "type 2"
18 ~~trading system embodiment of the present invention.~~ Figure 5 is
19 ~~a block diagram illustrating a "type 2" back-to-back trade~~
20 ~~using the present invention.~~

21 Figure ~~6~~5 is a block diagram illustrating an interlocking
22 network of type 1 and type 2 atomic units.

23 Figure ~~7~~6 is a schematic diagram illustrating trading
24 limits for a traded instrument being traded between four agents
25 4,5 using three trading channels 3.

1 Figure ~~8~~7 is a block diagram illustrating various ways
2 that agents 2 can be connected to enable them to use the
3 present invention.

4 Figure ~~9~~8 is a timeline illustrating an embodiment of the
5 matching process used in the present invention.

6 ~~Figure 10 is~~Figures 9A and 9B are a block diagram
7 illustrating an embodiment of the border outpost process of
8 the present invention.

9 Figure ~~11~~10 is a deal fulfillment graph.

10 Figure ~~12~~11 is a flow diagram illustrating the sequence of
11 screen shots appearing on the computer of an agent 2 using the
12 present invention.

13 Figure ~~13~~12 illustrates a log-in screen 21 of the computer
14 of an agent 2.

15 Figure ~~14~~13 illustrates a custom limit order book overview
16 window 24 (multiple traded instruments).

17 Figure ~~15~~14 illustrates a custom limit order book window
18 25 (single traded instrument).

19 Figure ~~16~~15 illustrates a net exposure monitor 35.

20 Figure ~~17~~16 illustrates a balance sheet window 36.

21 Figure ~~18~~17 illustrates an open order overview and
22 management window 33.

23 Figure ~~19~~18 illustrates a bid creation dialog box 28.

24 Figure ~~20~~19 illustrates an offer creation dialog box 29.

1 Figure ~~21~~20 illustrates a buy (immediate execution bid)
2 dialog box 30.

3 Figure ~~22~~21 illustrates a sell (immediate execution offer)
4 dialog box 31.

5 Figure 22 is a flow diagram illustrating the computation
6 of a custom limit order book 24,25.

7 ~~Figure 23~~ is a flow diagram illustrating the computation
8 ~~of a custom limit order book 24,25.~~ ~~Figure 24 is a flow diagram~~
9 ~~illustrating the computation of~~ multi-hop flow limits for a
10 single traded instrument among all accounts.
11

12 Figure ~~25~~24 is a flow diagram illustrating computation of
13 a directed graph of single-hop flow limits for a single traded
14 instrument among all accounts.

15 ~~Figure 26 is~~ Figures 25A and 25B are a flow diagram
16 illustrating computation of minimum and maximum excursions for
17 a single account A and a single traded instrument.
18

19 Figure 26 is a flow diagram illustrating computation of a
20 position limit for a lot instrument L.

21 Figure 27 is a flow diagram illustrating computation of a
22 position limit for a ~~lot~~quoted instrument LQ.

23 Figure 28 is a flow diagram illustrating computation of a
24 ~~position~~volume limit for a ~~quoted~~lot instrument QL.

25 Figure 29 is a flow diagram illustrating computation of a
26 volume limit for a ~~lot~~quoted instrument LQ.
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1 Figure 30 is a flow diagram illustrating computation of a
2 ~~volume~~notional position limit ~~for a quoted instrument Q.~~

3 Figure 31 is a flow diagram illustrating computation of a
4 notional ~~position~~volume limit.

5 Figure 32 is a flow diagram illustrating computation of a
6 ~~notional volume~~traded instrument L:Q position limit.

7 Figure 33 is a flow diagram illustrating computation of a
8 traded instrument L:Q ~~position~~volume limit.

9 Figure 34 is a flow diagram illustrating ~~computation of a~~
10 ~~traded instrument L:Q volume limit.~~ Figure 35 is a flow diagram
11 ~~illustrating~~ reporting by computer 1 of a single-hop trade.

12 Figure ~~36~~35 is a flow diagram illustrating reporting by
13 computer 1 of a multi-hop trade.

14 Detailed Description of the Preferred Embodiments

15 The present invention enables an arbitrary number of agents 2 of
16 arbitrary type (such as corporate treasuries, hedge funds,
17 mutual funds and other collective investment schemes, banks and
18 other financial institutions, and other institutions or
19 persons) to trade commodities and financial instrument pairs
20 directly amongst each other (thus facilitating client-to-
21 client, or C2C trading) by making orders to their peers to buy
22 and sell the traded instrument pairs over "credit atomic units"
23 and "credit molecules".

24 By way of example, the application highlighted most often
25 herein is the spot foreign exchange (spot FX) market, but it
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1 must be understood that the present invention has applicability
2 to trading in any type of over-the-counter commodity or
3 financial instrument, including physical commodities, energy
4 products (oil, gas, electricity), insurance and reinsurance
5 products, debt instruments, other foreign exchange products
6 (swaps), and compound instruments and other derivatives
7 composed or derived from these instruments.

8 A trade is the exchange of a lot of instrument L for a
9 quoted instrument Q. The lot instrument L is traded in an
10 integral multiple of a fixed quantity referred to as the lot
11 size. The quoted instrument Q is traded in a quantity
12 determined by the quantity of the lot instrument L and the
13 price. The price is expressed as Q per L. In a spot FX trade,
14 the lot instrument L and the quoted instrument Q are implicit
15 contracts for delivery of a currency on the "spot" date
16 (typically two business days after the trade date).
17

18 In the present specification and claims, entities that
19 wish to trade with each other are referred to as "agents" 2.
20 Agents 2 that extend credit to other agents 2 are referred to
21 as credit-extending agents 5. Agents 2 that do not extend
22 credit to other agents 2 are referred to as clients 4 or non-
23 credit-extending agents 4.
24

25 Two agents 2 may have direct trading channels 3 between
26 them, where the trading channels 3 correspond to credit
27 extended from one credit-extending agent 5 (typically a bank,
28

1 financial institution, or any clearing entity) to the other
2 agent 2. Trading channels 3 are typically secured via
3 placement of collateral (margin) or other form of trust by an
4 agent 2 with the credit-extending agent 5. Typically, trading
5 channels 3 amongst credit-extending agents 5 and non-credit-
6 extending agents 4 already exist. In the spot FX market, these
7 trading channels 3 are referred to as trading accounts. In the
8 case that two credit-extending agents 5 have a trading channel
9 3 between them, only one agent 2 acts in a credit-extending
10 capacity with regards to that trading channel 3.
11

12 Credit-extending agents 5 that allow the central computer
13 1 to utilize a portion of their trading channels 3 to allow
14 other agents 2 to trade with each other are referred to as
15 "credit-bridging agents" 5. In a preferred implementation of
16 the present system, existing banks, financial institutions, and
17 clearing entities are credit-bridging agents 5 as well as
18 credit-extending agents 5; and existing trading customers of
19 those institutions 5 are clients 4.
20

21 Compared with prior art systems, the present invention
22 gives a relative advantage to clients 4 compared to credit-
23 extending agents 5, by enabling one-way or two-way orders from
24 any agent 2 to be instantly displayed to all subscribing agents
25 2, enabling a trade to take place at a better price, with high
26 likelihood, than the price available to clients 4 under prior
27 art systems. The present invention brings together clients 4
28

1 who may be naturally on opposing sides of a trade, without
2 conventional spreads historically charged to them 4 by credit-
3 extending agents 5 for their 5 service as middlemen. Of
4 course, credit-extending agents 5 also benefit on occasions
5 when they are natural sellers or buyers.

6 Unlike prior art systems, the present invention arranges
7 multi-hop deals to match orders between natural buyers and
8 sellers who need not have a direct trading relationship. For
9 the application to spot FX trading, a multi-hop deal can be
10 realized through real or virtual back-to-back trades by one or
11 more credit-bridging agents 5. In terms of the underlying
12 transfers of financial instruments, a multi-hop deal is similar
13 to the existing practice of trade "give-ups" from one broker to
14 another.
15

16 Unlike prior art systems, the present invention computes
17 trading limits from not only cumulative volume but also from
18 net position limits, where both volume and position limits may
19 be set in terms of the traded instrument (instrument L for
20 instrument Q), in terms of any underlying instruments to be
21 exchanged (delivered) upon settlement (such as L individually,
22 Q individually, or other instruments), or in terms of the
23 notional valuations of such instruments. This allows all
24 agents 2, especially credit-bridging agents 5, to control risk
25 far more flexibly. Limiting traded or delivered instruments'
26 cumulative volume helps to manage settlement risk. Limiting a
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1 traded instrument's net position (net L:Q position) helps to
2 manage market risk. Limiting a delivered underlying
3 instrument's net position (total net L, total net Q, or some
4 other underlying instrument's position) helps manage market and
5 credit risk by reflecting the ultimate effect of any trade on
6 any account's future balance sheet. The cumulative volume
7 limits allowed by prior art systems are able to address only
8 settlement risk concerns.

9
10 The present invention has a natural symmetry; in the
11 preferred implementation, not only are credit-bridging agents 5
12 (financial institutions) able to operate as market makers and
13 post one-way (just a bid or ask) and two-way (both bid and ask)
14 prices to agents 2, but clients 4 may post one-way and two-way
15 prices to credit-bridging agents 5 and other clients 4 of any
16 other credit extending or credit bridging agent 5. This
17 symmetry is not present in prior art trading systems.

18
19 The present invention uses a central computer 1 to
20 calculate trading limits, to prepare custom limit order books
21 24,25, and to match orders, but all post-trade bookkeeping and
22 settlement is handled in a de-centralized manner by the
23 counterparties 2 involved in each trade. The central computer
24 1 is a network of at least one physical computer acting in a
25 closely coordinated fashion.

26
27 Every agent 2 subscribing to a system employing the
28 present invention can be thought of as a node 2 in an

undirected graph (Figs. 1-6, ~~11~~5, 10). The undirected edges 3 of such graphs indicate the existence of a trading channel 3 (account) between two nodes 2, typically an arrangement of trading privileges and limits based on the extension of credit from one node 2 to another 2 and likely backed by collateral placed by one node 2 with the other 2. Some nodes 5 in the graph, corresponding to credit-bridging agents 5, allow credit to be bridged, while other nodes 4 are clients 4 who permanently or temporarily forbid credit bridging. For the application to spot FX trading, a credit-bridging agent 5 authorizes the central computer 1 to initiate back-to-back spot trades, where simultaneous trades in opposite directions at the same price are made between the credit bridging agent 5 and two or more different agents 2, such that the net position effect to the credit bridging agent 5 is exactly zero.

For each trading channel (account) 3, the central computer 1 maintains a set of limits set by the credit-extending agent 5 and a set of limits set by the non-credit-extending agent 2. Either of these sets of limits may be empty. These limits specify maximums of cumulative volume of each traded instrument L:Q, maximum cumulative volume of an underlying instrument (e.g. L, Q, or other), maximum cumulative notional value (e.g. U.S. dollar equivalent), maximum positive or negative net position of each traded instrument L:Q, maximum positive or negative net position of the underlying instrument (e.g. L, Q,

1 or other), and maximum absolute net notional position (e.g.,
2 U.S. dollar equivalent) value total.

3 For each trading channel (account) 3, the central computer
4 1 maintains information sufficient to compute the current value
5 of all the quantities upon which limits may be placed. The
6 cumulative volume values are reset to zero with some period,
7 typically one business day, at such a time as is agreeable to
8 both agents. It is illustrative to note that the cumulative
9 volume values always increase toward their limit with each
10 trade, while the net position values may be decreased back to
11 zero or near zero and may change in sign.
12

13 An agent 2 may add, remove, or adjust any of the elements
14 of the set of limits specified by that agent 2 at any time.

15 Since trading is permitted or denied based on these limit-
16 related values, the central computer 1 provides a way for the
17 agents 2 that are parties to an account to inform the central
18 computer 1 of any external activity that would affect these
19 values, such as odd-lot trades and trades made through existing
20 trading devices, or to simply reset all limit-related values to
21 a predefined state.
22

23 Based on the current values of all these limit-related
24 quantities, the central computer 1 computes for each traded
25 instrument L:Q a directed graph (Figure 7.6) of maximum
26 excursions. In the directed graph for each traded instrument
27 L:Q, each directed edge 3 from a node 2 to another node 2 has a
28

1 value that indicates, based on the current position, how many
2 of the traded instrument L:Q may be bought by the first node 2
3 from the second node 2. There are typically directed edges 3
4 in both directions between any pair of nodes 2, since the
5 instrument L:Q may be bought or sold. The trading limit values
6 (maximum excursions) of these buying and selling edges 3
7 between two nodes 2 vary from moment to moment as trades are
8 made and/or credit limits are adjusted by either node 2.

9 For all traded instruments L:Q and for all nodes 2 that
10 trade L:Q and for all other nodes 2 that trade L:Q, the central
11 computer 1 uses the directed graph of maximum excursions (Fig.
12 7) to compute the maximum flow from the first node 2 to the
13 second node 2. Note that this means that each pair of nodes 2
14 that trade L:Q will have the maximum flow between them 2
15 calculated in both directions.

16 The prior art systems could be simulated by the present
17 invention by first eliminating the ability of any node 2 to be
18 a credit-bridging agent 5 so that the "single-pair maximum
19 flow" is merely the flow enabled by directed edges 3 connecting
20 the pair of nodes 2 directly. Second, all trading limits by
21 non-credit-extending agents 4 would be disabled and only
22 cumulative volume limits on underlying instruments would be
23 allowed for credit-extending agents 5, corresponding to limits
24 only on settlement risk.

1 For purposes of illustrating the present invention,
2 consider, for example, an agent A extending credit to agent B
3 for the purposes of trading spot FX using the present
4 invention, and between the U.S. dollar (USD), Euro (EUR), and
5 Japanese Yen (JPY) in particular. Suppose agent B buys 1 lot
6 of EUR:USD at 0.9250, then sells 1 lot of EUR:JPY at 110.25,
7 with both trades having agent A as counterparty 2. The first
8 trade will upon settlement result in 1,000,000 EUR received by
9 agent B and 925,000 USD paid by agent B, while the second trade
10 will result in 1,000,000 EUR paid by agent B and 110,250,000
11 JPY received by agent B. From the perspective of agent B, the
12 account stands +1M EUR toward the EUR:USD cumulative volume
13 limit, +1M EUR toward the EUR:USD net position limit, +1M EUR
14 toward the EUR:JPY cumulative volume limit, -1M EUR toward the
15 EUR:JPY net position limit, +2M EUR toward the EUR cumulative
16 volume limit, +925,000 USD toward the USD cumulative volume
17 limit, +110,250,000 JPY toward the JPY cumulative volume limit,
18 ZERO with respect to the EUR net position limit, -925,000 USD
19 toward the USD net position limit, and +110,250,000 JPY toward
20 the JPY net position limit. Further supposing that the
21 instrument valuations in agent B's home currency of USD are
22 0.9200 EUR:USD and 0.009090 JPY:USD, then the account stands
23 $(2M \times 0.9200 + 925,000 + 110,250,000 \times 0.009090 =)$ 3,767,172.50
24 USD toward the notional USD cumulative volume limit (useful for
25 limiting settlement risk), and $(0 \times 0.9200 + 925,000 +$
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110,250,000 x 0.009090 =) 1,927,172.34 USD toward the absolute
notional net position total.

Now suppose agent B buys 1 lot of USD:JPY at 121.50, which
upon settlement will result in 1,000,000 USD received and
121,500,000 JPY paid. The net single-instrument positions are
now 0 EUR, 75,000 USD, and -10,250,000 JPY. Rather than
delivering JPY at settlement (which will entail carrying a JPY
debit balance in the account), agent B will probably choose to
arrange an odd-lot deal with agent A to buy 10,250,000 JPY at a
rate of, for instance, 121.40 USD:JPY, at a cost of 84,431.63
USD, resulting in final account position values of 0 EUR, -
9,431.63 USD, and 0 JPY. In other words, agent B has lost
9,431.63 USD in its account with agent A once all the
settlements occur.

Alternatively, agent B may choose to "roll forward" any EUR or JPY
net position from the spot date to the next value date, or to
any forward date by buying or selling an appropriate FX swap
instrument from or to agent A.

Odd-lot spot, odd-lot forward, odd-lot swap, and deals
with a specific counterparty 2 are not amenable to trading via
the "limit-order book" matching system, but instead may be
facilitated by the central computer 1 through a request-for-
quote mechanism. Since the central computer 1 knows the net
positions of all the accounts, it may further recommend such
deals on a periodic basis, such as a particular time that both

1 agents 2 consider to be the end of the business day for the
2 account in question.

3 For the application of the present invention to markets
4 other than spot FX, triangular interactions between traded
5 instrument pairs are not as much a concern. The limits set by
6 credit-extending agents 5 are handled the same way, where the
7 limits on commodity holdings or currency payments are
8 translated by the central computer 1 into excursion limits (how
9 many lots an agent 2 may buy or sell) in real-time.
10

11 The present invention can be implemented in a combination
12 of hardware, firmware, and/or software. The software can be
13 written in any computer language, such as C, C++, Java, etc.,
14 or in a combination of computer languages. The hardware,
15 firmware, and software provide three levels of content: a)
16 trade screens, b) post-trade content for back offices and
17 clearing units, and c) real-time credit management content.
18 Through an API (application programming interface) 38, agents 2
19 can securely monitor and change in real time the credit limits
20 they have specified for each trading channel 3 in which they
21 participate. (Note that the maximum flow across a trading
22 channel 3 is the minimum of the trading limits specified by the
23 two agents 2 associated with the channel 3, so a non-credit-
24 extending agent 4 can only further reduce the credit limits
25 assigned by the credit-extending agent 5.)
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1 The link between the agents 2 and the central computer 1
2 can be any telecommunications link--wired, wireless, Internet,
3 private, etc. Computer 1 can be located anywhere in the world.
4 It can be mirrored for purposes of data backup, to increase
5 throughput, or for other reasons; in that case, there is a
6 second central computer 1(2). The backup central computer 1(2)
7 is a network of at least one physical computer operating in a
8 closely coordinated fashion. Such a backup computer 1(2) is
9 shown in ~~Fig. 8,~~ Figure 7, and insures that there will be no
10 interruption of service with hardware, software, or network 6,7
11 failures (neither during the failure nor during the needed
12 repairs); and further insures that the present invention has
13 the ability to recover from a disaster event.

15 Since the present invention operates on a global scale,
16 said operation has to satisfy local laws and regulations to
17 enable the services of the present invention to be provided.
18 The present invention is therefore designed to enable such
19 accommodations to be made.

21 The present invention supports purpose-specific "atomic
22 units" enabling trading between specific types of agents 2.
23 The basic atomic units are "type 0", "type 1", and "type 2",
24 where a "type 0 unit" involves a single pair of agents 2 where
25 one extends credit to the other, a "type 1 unit" involves a
26 single client 4 trading with a collection of credit-extending
27 agents 5, and a "type 2 unit" involves a single credit-bridging
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1 agent 5 enabling a collection of its clients 4 to trade with
2 itself 5 and with each other 4.

3 Figure 1 illustrates the simplest atomic unit, type 0. A
4 first agent 2(1) and a second agent 2(2) wish to trade at any
5 given time some number of round lots of instrument L in
6 exchange for a quantity of another item Q, which we refer to as
7 the quoted instrument or quoted currency. A trading channel 3
8 (account) between the two agents 2 allows for the execution of
9 the trades and settlement of the underlying instruments.
10 Inherent in the trading channel 3 are flow limits (trading
11 limits) on the items L,Q being traded and limits on any
12 underlying instruments exchanged upon settlement of the L,Q
13 trade. A central computer 1, under control of the operator or
14 owner of the system, is coupled to the two agents 2. The
15 computer 1 is adapted to convey to each agent 2 current bid
16 orders and offer orders originating from the other
17 participating agent 2. The current set of tradable bid and
18 offered prices and sizes is constrained by the trading
19 channel's trading limits, and is preferably conveyed in the
20 form of a custom limit order book 24,25 for each agent 2, as
21 will be more fully described below. The custom limit order
22 book 24, 25 is a chart, typically displayed on the agent's
23 computer, of a preselected number of bids and offers for the
24 instrument pair L,Q in order of price, and within price, by
25 date and time (oldest first).
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1 Typically, but not necessarily, each agent 2 is coupled to
2 the central computer 1 when the agents 2 are trading. The
3 identification of one of the two agents 2 as the "credit-
4 extending agent 5" is necessary only for the creation of a
5 trading channel 3, since either agent 2 may post orders (making
6 the market) in the same way.

7 Figure 2 illustrates the type 1 atomic unit: a client
8 agent 4 is looking to trade with several credit-extending
9 agents 5 with whom it 4 has a credit relationship. Note that
10 because each credit-extending agent 5 participates in only a
11 single trading channel 3 (with which the central computer 1 is
12 aware), there is no opportunity for the credit-extending agents
13 5 to act as credit-bridging agents 5. The type 1 scenario
14 involves the client 4 placing a one-way or a two-way order via
15 computer 1. Computer 1 insures that every institution 5 with
16 which the client 4 has a credit relationship sees the order
17 instantaneously. If none of the institutions 5 wish to deal at
18 the client's current price, they 5 may post their own counter-
19 offers that then appear on the client's custom limit order book
20 24,25, but not on those of the other institutions 5. The
21 client 4 may then choose to modify or cancel its 4 order to
22 deal at the best price possible, while the institutions 5
23 benefit by seeing this client's 4 possible interest in buying
24 or selling.
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1 The institutions 5 may also supply via computer 1 tradable
2 bid and offered prices to the client 4 that will not be seen by
3 the other institutions 5.

4 The solid lines in Figure 2 represent credit relationships
5 between client 4 and credit-extending agents 5. The credit-
6 extending agents 5 may have credit relationships outside the
7 scope of the present invention, but only those trading channels
8 3 whose credit limits are maintained by the central computer 1
9 are illustrated or discussed. The dashed lines in Figure 2
10 represent communication links between the agents (4,5) and the
11 central computer 1.
12

13 As a sub-species of type 1, there can be multiple clients
14 4, as long as all such clients 4 have credit relationships with
15 the same credit-extending agents 5, and the clients 4 are not
16 allowed to trade with each other 4.

17 Computer 1 provides several post-trade capabilities to the
18 client 4 and to the financial institution's 5 trading desk as
19 well as to its 5 back office and credit desk, all in real-time.
20

21 The clearing of the trade is done by conventional means.
22 The operator of computer 1, though it could, does not need to
23 act as a clearing agent and does not need to hold as collateral
24 or in trust any financial or other instruments. The client 4
25 can direct that all clearing is to be handled by a certain
26 credit-extending agent 5. The clearing procedures are
27 dependent upon the instruments traded and any netting
28

1 agreements or special commodity delivery procedures required
2 for those instruments.

3 The type 2 atomic unit is illustrated in Figure 4-3. Type
4 2 enables client 4 to client 4 dealing among the clients 4 of a
5 particular credit-bridging agent 5, as well as enabling client
6 4 to credit-extending agent 5 trading. As usual, the anonymous
7 order-matching process is triggered whenever an order to buy is
8 made at a price equal to or higher than the lowest outstanding
9 offer to sell, or vice versa. If the match is between a client
10 4 and the credit-bridging agent 5, then a single deal is booked
11 between those two parties 2. However, if the match is between
12 two clients 4, then two back-to-back deals are booked, one
13 between the seller client 4 and the credit-bridging agent 5,
14 and the other between the buyer client 4 and the credit-
15 bridging agent 5. This is akin to creating virtual trading
16 channels between the clients 4. A client 4 who has a credit
17 relationship with the credit-bridging agent 5 is able to post
18 its one-way or two-way order via computer 1, which causes the
19 order to be instantly displayed to all other clients 4 and to
20 the credit-bridging agent 5 itself if the existing credit
21 limits between the posting client 4, the credit-bridging agent
22 5, and the receiving client 4 would allow a portion of the
23 order to be executed.

24 This "mini-exchange" has the liquidity of the natural
25 supply and demand of the entire client 5 base, combined with
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1 the market-making liquidity that the credit-bridging agent 5
2 would be supplying to its clients 4 ordinarily. It is
3 certainly expected, and beneficial to the overall liquidity,
4 that the credit-bridging agent 5 will be able to realize
5 arbitrage profits between the prices posted by its clients 4
6 and the prices available to the credit-bridging agent 5 through
7 other sources of liquidity. In fact, there may be instances in
8 some markets where clients 4 are also able to arbitrage against
9 other trading systems.

10
11 Again, computer 1 provides several post-trade capabilities
12 to the client 4 and to the trading desk, the back office, and
13 the credit desk of the credit-bridging agent 5, all in real-
14 time, as in type 1.

15 A pair of back-to-back trades is illustrated in Figure
16 5-4, showing that agents 4(2) and 4(4) are the ultimate buyer
17 and seller of the deal, but they each deal only with the
18 credit-bridging agent 5 as their immediate counterparty 2.
19

20 As with all the various atomic units, central computer 1
21 updates the current tradable information after each trade, and
22 causes this information to be displayed on the computers
23 associated with all of the subscriber agents 2.

24 Again, computer 1 provides several post-trade capabilities
25 to the clients 4, as well as to the credit-bridging agent's 5
26 trading desk, its 5 back office, and its 5 credit desk, all in
27 real-time. The credit-bridging agent 5 acts as a clearing
28

1 agent for this trade, and is able to monitor the client-to-
2 client exposure, in real time.

3 Thus is created a price-discovery mechanism for end-users
4 2 with direct transparency between entities 2 wishing to take
5 opposite sides in the market for a particular instrument. The
6 present invention encompasses decentralized operation of an
7 arbitrary number of separate, type-1 and type-2 atomic units.
8 Efficient price discovery is provided to the end user 2 in a
9 decentralized liquidity rich auction environment, leveraging
10 existing relationships, and co-existing with and indeed
11 benefiting from traditional trading methodologies.
12

13 Furthermore, an arbitrary number of different type 0, type
14 1, and type 2 atomic units may be interconnected, bottom-up, as
15 illustrated in Fig. 6-5, to provide, at all times, a liquidity
16 rich efficient price-discovery mechanism to the subscribing
17 agents 2, enabling more and more agents 2, across different
18 atomic types, to conduct efficient direct auctions with each
19 other directly. The various atomic units may be interconnected
20 into a molecular credit-network.
21

22 In Figure 6-5, which may be considered to illustrate a
23 "type 3" scenario, shaded circles represent credit-bridging
24 agents 5 and un-shaded circles represent clients 4.

25 For purposes of simplicity, central computer 1 is not
26 shown on Fig. 6-5, but is in fact coupled to all nodes 2. Each
27 node 2 has proprietary client software on a computer associated
28

1 with said node 2, enabling said node 2 to communicate with
2 central computer 1. Such software may take the form of a Web
3 browser. The diameters of the arrow-headed lines 3 represent
4 instrument excursion limits deduced from each trading channel's
5 various types of credit limits. A "shortest weighted paths"
6 algorithm or other minimum cost flow algorithm is used to
7 calculate the minimal path between two agents 2 subject to
8 credit flows to enable a trade between the agents 2. The
9 trading agents 2 may be arbitrarily removed from one another,
10 both in geographic terms as well as by type of business
11 activity in which they 2 are involved.
12

13 Each connected piece of Fig. 65 maintains full
14 transparency of orders posted on computer 1 to all financial
15 institutions 5 and clients 4 who are on any unexhausted credit
16 path 3 to the posting entity 2. Each of the entities 2 who are
17 able to see the posted order are in effect competing, through
18 the reverse auction, for that particular deal, enabling further
19 efficient price-discovery to the posting entity 2.
20

21 Prior to each trade, computer 1 internally computes the
22 values that define one of these Figure 65 graphs for each pair
23 of instruments being traded. From the graph, computer 1
24 creates a table of multi-hop trading limits showing the trading
25 limits between each pair of nodes 2. From the table of multi-
26 hop trading limits, computer 1 prepares a custom limit order
27 book 24,25 for each node 2 for each traded instrument pair.
28

1 After every trade, computer 1 recalculates the trading limits
2 3, thus leading to a new graph (Figure ~~6~~5) for that instrument
3 pair. Recalculating the trading limits 3 for a given traded
4 instrument pair can affect the topology (trading limits 3) of
5 other graphs (Figure ~~6~~5) for other traded instrument pairs.
6 This can occur, for example, when the trading limits are
7 notional trading limits.

8 On Figure ~~6~~75, if an agent 2 has imposed its own internal
9 limits that are smaller than the trading limits that have been
10 imposed by a credit-extending agent 5 that is extending it 2
11 credit, computer 1 uses the smaller of the two limits when it
12 creates Figure ~~6~~5.

14 Each trading channel 3 represents an account between a
15 credit-extending agent and a client agent 4. In the preferred
16 implementation of this invention, all credit-extending agents
17 are credit-bridging agents 5. Even when two adjacent nodes 2
18 are fully qualified to be credit-extending agents 5, one acts
19 as the credit-extending agent 5 in the transaction and the
20 other acts as the client agent 4 in the transaction. The
21 accounts that exist between credit-extending agents 5 and
22 client agents 4 comprise specified input credit limits, balance
23 holdings, and collateral; computer 1 calculates trading limits
24 from this information.

26 The operator of computer 1 typically has, in its standard
27 agreement with a subscribing agent 2, language stating that if
28

1 the agent 2 has entered into a written subscription agreement
2 with the operator of computer 1 and said agent 2 trades outside
3 of the network 6,7 operated by the operator of computer 1, that
4 agent 2 is obligated to notify the operator of computer 1 about
5 such outside trades, so that computer 1 can recalculate the
6 trading limits as necessary.

7 Figure 65 can be thought of as an n-hop credit network,
8 where n is an arbitrary positive integer. In any transaction,
9 the instrument flow can fan out from one source node 2 and then
10 collapse to the destination node 2; the instrument flow does
11 not have to stay together as it flows from the source 2 to the
12 destination 2. See Fig. ~~11~~10 for an example of this
13 phenomenon. In calculating the maximum capacity of the network
14 6,7, computer 1 uses a maximum flow algorithm such as one
15 described in chapter 7 of the Ahuja reference cited previously.
16 In determining the actual flow used to complete the trade,
17 computer 1 uses a minimum cost flow algorithm such as one
18 described in chapter 9 of said Ahuja reference, where the cost
19 to be minimized is a function of the actual cost to execute the
20 trade and other factors, such as projected settlement costs,
21 flow balancing heuristics, and a randomizing component.

24 The network 6,7 of Figure 65 is a non-disjointed network.
25 By that is meant that every node 2 in the network 6,7 is
26 coupled to at least one other node 2, and at least one of the
27 agents 2 associated with each trading channel 3 is a credit-
28

1 bridging agent 5. The individual trading limits 3 that
2 computer 1 computes for each agent 2 pair are dependent upon
3 the topology of the network 6,7. Computer 1 essentially
4 transforms the network 6,7 into a virtually cliqued networked.
5 A "cliqued network" is one in which every node 2 is connected
6 to every other node 2. A "virtually cliqued network" is one in
7 which every node 2 has a capability to trade with every other
8 node 2, but not necessarily directly. In order to preserve the
9 desired feature of anonymity, each node 2 knows the identities
10 of only its immediate trading partners 2, and does not
11 necessarily know whom 2 it is actually trading with.
12

13 As a trading system that leverages the existing
14 relationships in the market for the traded instrument, the
15 present invention provides all market players 2 (typically
16 banks, financial institutions, clearing entities, hedge funds,
17 and any corporations or other entities) the ability to trade
18 directly with each other through a custom limit order book
19
20 24,25. These agents 2 may already be connected together with
21 credit relationships, but prior art systems allow trading only
22 between two parties that have an explicit credit arrangement.
23 The present invention analyzes the credit-worthiness of a
24 potential counterparty 2 at a higher level, performing this
25 analysis in real time, and providing each party 2 with a limit
26 order book 24,25 customized to its 2 current credit
27 availability.
28

1 For example, in Figure 76 we consider a small network of
2 foreign exchange players: banks 5(B) and 5(C), which have a
3 credit relationship with each other, and clients 4(A) and 4(D),
4 who have margin placed with banks 5(B) and 5(C), respectively
5 (we leave the margin currency and traded instrument
6 unspecified). The specified input credit limits are specified
7 as traded instrument L:Q credit limits (just one way of
8 specifying input credit limits out of eight possible ways
9 enumerated in the present patent application). Client 4(A)'s
10 margin allows it to trade +/- 10M with 5(B), 5(B)'s
11 relationship allows it to trade +/- 50M with 5(C), and 5(D)'s
12 margin allows it to trade +/- 5M with 5(C). This information
13 is supplied to computer 1, which draws Figure 76 from said
14 information.
15

16 Figure 76 illustrates a simplified type 3 network in which
17 there are two client agents 4 and two credit-extending agents 5
18 which are also credit-bridging agents 5. Figure 76 also
19 illustrates the trading limits between each pair of coupled
20 agents 4,5. Table 1 shows the maximum multi-hop credit limits
21 that are then calculated by computer 1 for the simplified
22 network of Figure 76 as follows:
23
24
25
26

27 Table 1:

28 A B C D

1	A	infinity	10M	10M	5M
2	B	10M	infinity	50M	5M
3	C	10M	50M	infinity	5M
4	D	5M	5M	5M	infinity

5
6 Computer 1 then uses the information contained in Table 1
7 to create a custom limit order book 24,25 for each agent A, B,
8 C, D, and causes the custom limit order book 24,25 to be
9 displayed on the computer screen of the respective agent A, B,
10 C, D. The filtered bids and offers in the custom limit order
11 book 24,25 are for volumes that are an integral multiple of the
12 lot size even if the computed Table 1 amounts contain values
13 which are not integral multiples of the lot size, with non-
14 integral multiples rounded toward 0.
15

16 If client A posts a bid for 10M, computer 1 causes the
17 full bid to appear on the custom limit order books 24,25 of
18 banks B and C, and computer 1 causes a filtered bid for 5M to
19 appear on the custom limit order book 24,25 of client D,
20 because the maximum credit (implicit or explicit) available
21 between A and D is +/- \$5M. If there is no implicit or explicit
22 credit available between two nodes 2, they 2 are not allowed to
23 see each other's bids and offers at all on their custom limit
24 order books 24,25.
25

26 The network 6,7 of the present invention is preferably
27 built using the Internet Protocol (IP) (because of its
28

ubiquity), and may reside on the Internet itself or other public IP network 7 (Fig. 8-7).

It is also possible to locate part or all of the network 6,7 on a private fiber backbone 6, so that information bound for the Internet 7 can traverse most of the distance to its destination on the presumably higher speed private network 6. The slower public Internet 7 is then used for just the last segment of travel. It is also possible to provide clients 2 with dedicated bandwidth through private IP networks 6 in order to provide additional levels of quality and service. A single dedicated connection 6 may be backed up by an Internet connection 7, or multiple private connections 6 can be used to avoid the public network 7 entirely.

On Figure 8-7, the three illustrated agents 2 can be three separate companies, three computers within the same company, or a hybrid of the above.

The network 6,7 interfaces with both people and automated systems (computers), so it provides three access methods:

- human -- Graphical User Interface (standalone or browser-based application) for trading, interactive queries, and account management;
- human/computer -- HTTP reports interface (HTML, XML, PDF, or Excel) for queries only;

1 •computer -- Application Programming Interface 38 (available
2 in Java and COBRA with bridges to FIX, JMS, SOAP, and
3 ebXML) for trading, queries, and account management.

4 An agent's 2 software can be launched from the agent's 2
5 browser but run as a standalone application for better
6 performance and stability.

7 The computer of each agent 2 can have associated therewith
8 an application programming interface (API) 38. The API 38 is a
9 standard interface exposed by the central computer 1 that
10 enables the user 2 to write customized instructions enabling
11 two-way communication between central computer 1 and the user
12 2. In the case where the user 2 is a credit extending agent 5,
13 the API 38 can be used to update the agent's backoffice
14 information. The agent 2 can program his API 38 to make and
15 cancel orders (bids and/or offers). The agent 2 can use his
16 API 38 to receive and reformat custom limit order books 24,25
17 for any instruments. The agent 2 can use his API 38 to set
18 trading limits, with the understanding that the actual trading
19 limits are the minimum of the trading limits specified by the
20 two agents 4,5 associated with an account. The API 38 can be
21 programmed to estimate how much it would cost an agent 2 to
22 liquidate his position in an instrument. The API 38 can be
23 programmed to estimate that agent's profit/loss amount for each
24 instrument being traded; this information can be combined with
25 the agent's custom limit order book 24, 25. Anything that can
26
27
28

1 be achieved by the GUI (graphical user interface) (Figs. ~~13~~12-
2 ~~22~~21) can be achieved via the API 38.

3 Any and all features of the API 38 can be programmed to
4 operate automatically, including automatic bidding, offering,
5 buying, and selling. Automated processes accessing computer 1
6 via application programming interface 38 or a bridge use the
7 same cryptographic protocols as for a human agent 2 inputting
8 instructions via his computer's GUI. Whether an API 38 or a
9 GUI is used, an agent's private key for computerized access to
10 computer 1 can be stored in the agent's computer, provided said
11 computer has sufficient security safeguards.
12

13 Privacy, authentication, and non-repudiation are achieved
14 in the present invention via the use of cryptography in a
15 variety of different forms. The cryptographic techniques can
16 comprise symmetric key and/or asymmetric key (public key)
17 cryptography. All data streams are encrypted, e.g., by using
18 SSL (Secure Socket Layer) connections or a combination of SSL
19 encryption with additional authentication and encryption.
20 Authentication can be required between computer 1 and an agent
21 2 at any and all times these devices 1,2 communicate with each
22 other. This authentication can be achieved through the use of
23 digital certificates. Revalidation of credentials can be
24 required at the time a trade is consummated.
25

26 Each agent 2 may store its private key on a tamper-
27 resistant hardware device such as a smartcard, protected by a
28

1 password. The combination of a physical token (the card) with
2 a logical token (the password) ensures two levels of security.
3 The hardware token may contain a small CPU that allows it to
4 perform the necessary cryptographic operations internally, so
5 that the agent's private key never leaves the smartcard. In a
6 preferred embodiment, computer 1 handles bulk
7 encryption/decryption using symmetric key cryptography after
8 the slower public key cryptography has been used to exchange a
9 session key between agent 2 and computer 1.
10

11 While trading in the present invention is peer-to-peer,
12 order matching for any particular instrument is done at a
13 centralized location 1 to maintain transactional integrity.
14 Figure 98 illustrates the order matching process. In step 8,
15 the first agent 2(1) places a bid via its software to computer
16 1, which accepts the bid at step 9. Computer 1 then calculates
17 changes to the custom limit order books 24,25 of agents 2(1)
18 and 2(2) at steps 10 and 11, respectively, taking into account
19 appropriate trading limits 3. At step 12, the second agent
20 2(2) takes the bid. Step 12 occurs right before step 13, in
21 which a third agent 2(3) (not illustrated) posts a new offer
22 (bid or offer) for the traded instrument L:Q. At step 14,
23 computer 1 makes the match between the first agent 2(1) and the
24 second agent 2(2).
25

26 Reporting of the trade is described below in conjunction
27 with Figs. 35 and 36.
28

1 A network 6,7 implementing the present invention can span
2 the entire world, which means that there may be time
3 differences for a message sent by different agents 2 to
4 computer 1. Assuming a network 6,7 that sends signals at the
5 speed of light but that cannot transmit through the Earth, a
6 message sent to the other side of the Earth would have a round-
7 trip time of at least 130 milliseconds. On existing IP
8 networks, it is observed that if the central computer 1 were
9 located in New York, the maximum average round-trip
10 communication time between the central computer 1 and a
11 computer in any of the major financial centers is less than 300
12 milliseconds.
13

14 We want to ensure that all agents 2 have a level playing
15 field in accessing computer 1, regardless of where these agents
16 2 are situated around the world. Determining the latency for
17 each agent 2 and then introducing an individual delay on an
18 agent-by-agent basis to try to equalize time-of-arrival at
19 computer 1 would be very difficult (due to short term
20 fluctuations in network 6,7 lag), and could have the undesired
21 effect of overcompensating. A malicious agent 2 could also
22 falsify its network 6,7 delay, unfairly obtaining early access
23 to computer 1.
24

25 In order to compensate for the various time lags in
26 sending messages between agents 2 and computer 1 on a global
27 basis, the present invention transmits information as rapidly
28

1 as possible while flagging the order of messages to compensate
2 for latency. The flagging is done by means of border outpost
3 computers 16 (Figure 10).—9).

4 For agents 2 remote from computer 1, a border outpost
5 computer 16 is inserted into the network 6,7, typically where
6 the agent's data enters the private backbone 6 that connects to
7 computer 1. Each border outpost computer 16 comprises a CPU
8 18, a trusted time source 17, and an input/output port 19.
9 Time source 17, which may comprise a GPS clock accurate to a
10 millionth of a second, is used to generate a digital time stamp
11 that is added to each data packet before it is forwarded to
12 computer 1. The GPS clocks 17 of all the border outpost
13 computers 16 are synchronized with each other to a high degree
14 of accuracy (typically one microsecond). The time stamp may be
15 placed onto the packet without the border outpost computer 16
16 having to understand the packet or have access to its contents.
17 At the computer 1 site, the time stamp is stripped off before
18 the packet is processed, and then reassociated with the data
19 after it is decrypted and parsed into a command. Computer 1
20 then sorts the messages into a queue by time order. After a
21 fixed time delay, the message that is at the front of the queue
22 is serviced by computer 1. The fixed time delay is chosen so
23 that with a high degree of certainty a message from the
24 remotest agent's 2 computer will arrive at computer 1 within
25 the fixed time delay. The purpose of the fixed time delay is
26
27
28

1 to allow all messages that might be the first-originated
2 message to have a chance to arrive at computer 1 before
3 execution of any messages takes place. The time stamp may be
4 encrypted using either a symmetric or assymetric cipher, to
5 prevent its modification or falsification.

6 Figure ~~11~~10 is a deal fulfillment (flow) graph,
7 illustrating the flow in the lot instrument. The lot
8 instrument L is the portion of the traded instrument that has
9 to be traded in a round lot, typically a multiple of a million.
10 The quoted instrument Q is that portion of the instrument being
11 traded that is expressed as the lot instrument times a price.
12 In this example, agent 4(2) buys 10M Euros using U.S. dollars
13 at an exchange rate of 0.9250 from agent 4(1). Since the Euro
14 is the lot currency in this example, it has to be specified in
15 a round lot (multiple of 1 million Euros). $F(L)$, the lot size
16 (volume), is 10 million and $F(Q)$, the quoted volume, is
17 9,250,000. In this example, there are three intermediaries
18 (middlemen): agents 5(1), 5(2), and 5(3). Only credit-bridging
19 agents 5 can be middlemen. For purposes of simplification, we
20 show on Figure ~~11~~10 the flow of just the lot instrument L.
21 There is also a counterflow in the quoted instrument Q, which
22 can be derived from the lot flow and the traded price. For
23 example, on the edge 3 between node 5(1) and 4(2,) 2M
24 represents the flow of 2 million Euros from agent 5(1) to agent
25
26
27
28

1 4(2), as well as the counterflow of 1,850,000 U.S. dollars from
2 agent 4(2) to agent 5(1).

3 Figure ~~12~~11, a simplified focus change diagram,
4 illustrates the sequence of screen shots appearing on the
5 display of a computer of an agent 2 who is coupled to central
6 computer 1. Agent 2 first encounters a log-in dialog box 21,
7 then a menu bar 22 where he can select from an account
8 management dialog box 23, a net exposure screen 35, a balance
9 sheet 36, or his custom limit order book 24,25. From custom
10 limit order book overview screen 24, agent 2 can navigate to
11 one of N order book detail screens 25, or to an activity dialog
12 screen 27, which can take the form of a bid dialog box 28, an
13 offer dialog box 29, a buy dialog box 30, a sell dialog box 31,
14 or a market order screen 32. As shown in Figure ~~12~~11, various
15 of these screens can segue into a bid/offer cancel dialog box
16 33 or a confirmation dialog box 34.

17
18 Figures ~~13~~12-~~22~~21 illustrate most of the above screens.
19 The login screen is shown (Figure ~~13~~12), followed by two shots
20 of the main desktop (Figures ~~14~~13 and ~~15~~14) showing the custom
21 limit order book overview window 24 and the custom limit order
22 book detail window 25. The remaining screen shots (Figs. ~~16~~15-
23 ~~22~~21) are of dialog boxes that can be activated from either the
24 overview window 24 or detail order windows 25.
25

26 Figure ~~13~~12 illustrates log-in dialog box 21. Field 41
27 allows agent 2 to type in his name, thus identifying the
28

1 account and trader. Field 42 is an optional challenge field,
2 provided for security purposes. An appropriate response from
3 the agent 2 to meet the challenge might include presentation of
4 a password, key, or digital certificate via a hardware token.
5 Field 43 is where agent 2 enters his password. Field 44 is
6 where agent 2 enters the address of central computer 1. In the
7 case of an Internet connection, the URL of computer 1 is
8 specified here. The data exchange between agent 2 and central
9 computer 1 is encrypted, e.g., by a SSL (Secure Socket Layer)
10 connection. Field 45 is a scrolling message log showing status
11 and notification of errors during the log-in process.
12

13 Figure ~~14~~13 illustrates the main custom limit order book
14 screen 24. Field 51 specifies the current account. Field 52
15 is a summary of the custom limit order book for each
16 permissioned traded instrument. In this sample, where the
17 instruments are pairs of currencies, the traded instruments are
18 identified by icons representing the flags of the countries
19 issuing the currencies. There are five fields 52 illustrated,
20 representing five permissioned instruments. The second field
21 52 from the top (Great Britain pounds for U.S. dollars) is
22 exploded, indicating the traded instrument currently activated
23 by agent 2.
24

25 Field 53 displays the top (best) orders from the point of
26 view of the agent 2. Field 54 displays the best bid price for
27 any agent 2 coupled to the network 6,7. Field 55 displays the
28

1 last two digits ("84") of the best available bid price. Field
2 56 displays the size at the best bid price. Field 57 displays
3 agent 2's available liquidity for additional selling. Field 58
4 provides agent 2 with a mouse-clickable area (the big figure)
5 enabling the agent 2 to jump to the buy or sell dialog screen
6 30 or 31, with amounts already filled in. Field 59 is a mouse-
7 clickable numeric keypad allowing the agent 2 to create and
8 cancel orders. Field 60 gives balance sheet values showing
9 live valuations at market price and the profit that was banked
10 by agent 2 for a certain period of time, such as the current
11 day. Field 61 is a pop-up console allowing for the display of
12 application messages, connection failure/retry messages, and
13 broadcast messages from central computer 1. Field 62 displays
14 the time since the agent 2 has logged in to computer 1. Field
15 63 displays the best available offer; in this case, four digits
16 of the available offer are used to warn agent 2 that his best
17 available offer is far from the overall best, due to a credit
18 bottleneck. Field 64 shows this agent's orders in red. Field
19 65 shows this agent's current net position in the instrument
20 being traded. Field 66 shows a summary of this agent's offers.
21 Field 67 is a mouse-clickable area (tab 9) enabling the agent 2
22 to quickly cancel the top offer.

23 Figure ~~15~~14 illustrates a custom limit order book depth
24 window 25. There are N of these windows 25 for each
25 instrument, where N is any preselected positive integer.
26
27
28

Typically, N is equal to five. The N windows 25 display the N best bids and offers in order of price, and within price, in order of date and time, with the oldest presented first. Field 71 shows bid and offer information, with the last two digits of the bid and offer ("99" and "02", respectively) displayed in large numerals for readability. Field 72 shows visible (to that agent 2) bids and offers truncated by current credit availability, individually or aggregated by price (configurable). Bids and offers from this agent's account are shown in pink. Field 73 is a mouse-clickable field allowing agent 2 to navigate to screen 33 (Fig. ~~18~~17). Field 74 is a set of four mouse-clickable areas enabling agent 2 to open buy, sell, bid, and offer dialog boxes (30, 31, 28, and 29, respectively), with price and size information pre-loaded from the current market.

Figure ~~16~~15 illustrates net exposure monitor 35. Each entry 81 gives the current exposure for each account, broken down by traded instrument. Field 82 ("min" and "max") shows asymmetric net position limits on a per-instrument basis. Field 83 ("current") shows a real-time update of net position. Field 84 shows a graphical representation of net position.

Figure ~~17~~16 illustrates balance sheet window 36. Field 91 shows payables and receivables, valued using the current market price. Total net position and net position for each counterparty 2 are given. Field 91 is organized as a tree

1 hierarchy, and allows navigation to individual balance sheet
2 transfers. Field 94 shows underlying flows; they have been
3 sent to the agent's computer in an encrypted form, and are
4 decrypted at the agent's computer. The decryption can be done
5 automatically, as long as the agent 2 is logged in to the
6 network 6,7. In field 94, one line represents each trade this
7 agent 2 has made, or each trade for which this agent 2 was an
8 intermediary 5. All values are live. This currency-based
9 balance sheet 36 is capable of handling triangular instrument
10 swaps.

11
12 Figure ~~18~~17 illustrates the open order overview and
13 management window 33. Field 101 shows orders (bids and offers)
14 currently placed by that agent summarized by traded instrument.
15 Field 102 shows individual orders. Field 103 is a mouse-
16 clickable area enabling the agent 2 to remove the order from
17 the agent's custom limit order book 24,25. All values are
18 updated immediately if their value has changed. In screen 33,
19 an update procedure can be implemented in which the first offer
20 is not cancelled until a new offer is posted. This is
21 sometimes referred to as OCO (one cancels the other). In any
22 event, it is never possible for an agent 2 to cancel an order
23 after it has been taken by a counterparty 2.

24
25 Figure ~~19~~18 illustrates bid creation dialog box 28. Field
26 111 is a group of icons, typically in various colors to provide
27 visual context to reduce errors. Note that the word "Bid" is
28

1 highlighted. Field 112 comprises three mouse-clickable areas
2 allowing for quick up or down adjustment of price and direct
3 entry of price, respectively, with initial value taken from the
4 current market. Field 113 comprises three mouse-clickable
5 areas allowing for quick up or down adjustment of size, and
6 direct entry of size, with initial value configurable based
7 upon the desires of the particular agent 2. Field 114 is a
8 mouse-clickable area allowing the agent 2 to submit the bid,
9 and has an optional confirmation dialog box associated
10 therewith. An agent 2 can post his bid for just a short period
11 of time and then withdraw it. He 2 can post multiple bids at
12 multiple prices. When a counterparty 2 takes part or all of
13 his bid, computer 1 recalculates the trading limits. Agent 2
14 can make his bid limited to "only if it is available now" or as
15 an offer to buy.
16

17 Figure ~~20~~19 illustrates offer creation dialog box 29.
18 Field 121 comprises a set of icons, typically colored to
19 provide visual context to reduce errors. Note that the word
20 "Offer" is highlighted. Field 122 comprises three mouse-
21 clickable areas allowing agent 2 to quickly achieve up or down
22 adjustment of price and direct entry of price, with initial
23 value taken from the current market. Field 123 comprises three
24 mouse-clickable areas providing a quick means for agent 2 to
25 achieve up or down adjustment of size and direct entry of size,
26 with initial value configurable on a per user 2 basis. Field
27
28

124 is a mouse-clickable area allowing agent 2 to post the offer, and has an optional confirmation dialog box associated therewith.

Figure ~~21~~20 illustrates buy (immediate execution bid) dialog box 30. Field 131 comprises a set of icons, typically colored to provide visual context to reduce errors. Note that the word "Buy" is highlighted. Field 132 comprises three mouse-clickable areas, providing a quick means for up or down adjustment of price and direct entry of price, with initial value taken from the current market. Field 133 is a mouse-clickable button allowing for a partial execution of a trade. This allows agent 2 to buy either as much of the size as possible, or nothing if he cannot buy the entire size. Field 134 comprises three mouse-clickable areas providing a quick means for up or down adjustment of size and direct entry of size, with initial value configurable on a per user 2 basis. Field 135 is a mouse-clickable area allowing agent 2 to execute the buy, and has an optional confirmation dialog box associated therewith.

Figure ~~22~~21 illustrates sell (immediate execution offer) dialog box 31. Field 141 is a set of icons, typically colored to provide visual context to reduce errors. Note that the word "Sell" is highlighted. Field 142 comprises three mouse-clickable areas providing a quick means for agent 2 to achieve up or down adjustment of price and direct entry of price, with

1 initial value taken from the current market. Field 143 is a
2 mouse-clickable area allowing partial execution. This allows
3 agent 2 the choice of the sell being either to fill as much of
4 the size as possible, or to not sell if he 2 cannot sell the
5 entire size. Field 144 comprises three mouse-clickable areas
6 providing for a quick means for up or down adjustment of size
7 and direct entry of size, with initial value configurable on a
8 per user 2 basis. Field 145 is a mouse-clickable area allowing
9 the sell to be executed, and has an optional confirmation
10 dialog box associated therewith.
11

12 Figure ~~23~~22 is a flow diagram illustrating the method
13 steps by which computer 1 computes a custom limit order book
14 24,25 for a single agent 2 for a single traded instrument.
15 Even intermediate agents 5 get a custom limit order book 24,
16 25. For the left hand side of Fig. ~~23~~22, source S is that
17 node 2 for which this custom limit order book is being
18 prepared; and sink T is that node 2 that has posted the bid.
19 For the right hand side of Figure ~~23~~22, source S is that node
20 2 that posted the offer; and sink T is that node 2 for which
21 this custom limit order book is being prepared. "Source" and
22 "sink" are standard network terminologies; see, e.g., the Ahuja
23 reference previously cited. These concepts are used internally
24 by computer 1, but are not disclosed to all agents 2 for
25 reasons of preserving the desired anonymity. For example, the
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1 actual poster 2 of the offer does not appear on the screen of
2 the counterparty 2.

3 The method starts at step 151. In step 152, computer 1
4 asks whether there have been any trades made since the last
5 multi-hop credit computation. This is meant to avoid
6 unnecessary computation. If the answer to the question is
7 "yes", then step 153 is executed. At step 153, multi-hop
8 credit limits are computed, as illustrated in Fig. ~~24~~23. If
9 the answer to the question raised in step 152 is "no", step 154
10 is executed. At step 154, the bid side of the book is cleared,
11 i.e., variable B becomes the null set; the offer side of the
12 book is cleared, i.e., variable A becomes the null set; and the
13 credit used (U as a function of S and T) is cleared. In this
14 context, "used" applies only for this particular custom limit
15 order book 24,25 for this particular agent 2. Step 155 is then
16 executed, where it is asked whether enough bids have been
17 found. "Enough" is a pre-established limit, e.g., five, and
18 corresponds to N as discussed above in conjunction with custom
19 limit order book detail window 25. N may be infinity, in which
20 case the method always proceeds from step 155 to step 156. If
21 enough bids have been found, the method proceeds to step 161.
22 If enough bids have not been found, the method proceeds to step
23 156, where it is asked whether there are more unprocessed bids,
24 i.e., if the number of bids that have been processed is less
25 that the pre-established limit. If the answer is "no", step
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1 161 is executed; otherwise, the method proceeds to step 157,
2 where the highest priced oldest unprocessed bid is fetched.
3 The hierarchy is according to highest bid. If there is a tie
4 as to two or more highest bids, then the bids are ordered by
5 time. It is forced that there not be a time-tie at this point;
6 time collisions have already been resolved by locking using
7 sequence numbers.

8 Step 158 is then executed. X is defined as the flow limit
9 (trading limit) between S and T minus the credit U between S
10 and T that has already been used up. Y is then set to be the
11 minimum of X and the bid size. In other words, Y is what we
12 have to work with. Step 159 is executed, where it is asked
13 whether Y is greater than 0. If not, the method cycles back to
14 step 155. If "yes", step 160 is executed. In step 160, the
15 set of bids B is augmented by the current bid we are working
16 with from step 157. Also in step 160, the credit used U is
17 augmented by Y.
18

19
20 At step 161, it is asked whether enough offers have been
21 found. Again, "enough" is a pre-established limit e.g., five,
22 corresponding to N as before. If the answer to this is "yes",
23 the method stops at step 167. If the answer is "no", step 162
24 is executed. At step 162, it is asked whether there are more
25 unprocessed offers. If not, the method ends at step 167. If
26 "yes", step 163 is executed, where the lowest priced, oldest
27 unprocessed offer is fetched. Then, step 164 is executed,
28

1 where X is set to be the trading limit between S and T minus
2 the unused credit U. Y is then set to be the minimum of X and
3 the offer size. Step 165 is then executed. At step 165, it is
4 asked whether Y is greater than 0. If not, control is passed
5 back to step 161. If "yes", step 166 is executed, where the
6 current offer price being worked on from box 163 is added to
7 the set of offers A; and the credit used U is augmented by Y.
8 Control then passes back to step 161.

9
10 Figure ~~24~~23 illustrates how computer 1 calculates multi-
11 hop trading limits for each pair of agents 2 for a single
12 traded instrument L:Q, i.e., how computer 1 performs step 153
13 on Figure ~~23~~22. This is akin to compiling a table like Table
14 1 shown above. This procedure starts at step 171. At step
15 172, a directed graph is computed for the traded instrument
16 L:Q, in which the arrow corresponds to the direction of flow of
17 the lot instrument L. Individual trading limits are introduced
18 at this point. Step 172 is the subject of Figure ~~25~~24. At
19 step 173, an arbitrary network node 2 is selected to be the
20 first node worked upon by the process and is given the
21 designation source S. At step 174, sink T is also set to be
22 said first network node 2. At step 175, it is asked whether S
23 is equal to T. If so (which, of course, is the case
24 initially), the procedure moves to step 176, where the maximum
25 flow limit between S and T is set to be infinity. This is
26 simply another way of saying that an agent 2 is allowed to have
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28

1 an infinite flow with himself 2. Then, at step 182, it is
2 asked whether T is the last network node that needs to be
3 processed. If "yes", control is passed to step 184; if "no",
4 control is passed to step 183, where T is advanced to the next
5 network node; and control is passed back to step 175. "Next"
6 can be anything, because the order of processing is of no
7 import.

8 If S is found not to be equal to T at step 175, control is
9 passed to step 177, which disables edges 3 where the edge
10 origin 2 is not a credit bridge 5 and the edge origin 2 is not
11 equal to S. An edge 3 may be disabled internally by adjusting
12 its maximum capacity to 0 or by removing it from the set of
13 edges 3 that comprise the graph. The "edge origin" is that
14 node 2 from which the lot instrument L flows. Steps 177 and
15 178 eliminate agents 2 who have not agreed in advance to be
16 intermediaries, i.e., "credit bridges". An intermediary
17 (credit bridge) is an agent 5 that allows two other agents 2 to
18 do back-to-back trades through the intermediary agent 5. Step
19 178 disables edges 3 where the edge destination 2 is not a
20 credit bridge 5 and the edge destination 2 is not equal to T.
21 An "edge destination" is a node 2 that receives the flow of the
22 lot instrument L.

23 At step 179, the maximal flow from S to T is computed
24 using a maximal flow algorithm such as one of the algorithms
25 disclosed in Chapter 7 of the Ahuja reference previously cited.
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1 At step 180, the multi-hop credit limit between S and T,
2 LIM(S,T), is set to be equal to the maximum flow obtained from
3 step 179. At step 181, the edges 3 that were disabled in steps
4 177 and 178 are re-enabled. Step 184 asks whether S is the
5 last network node to be processed. If "yes", the procedure
6 concludes at step 186. If "no", the process moves to step 185,
7 where S is advanced to the next network node. Again, "next" is
8 arbitrary and simply refers to any other unprocessed node 2.
9 After step 185, the method re-executes steps 174.

10
11 Figure ~~25~~24 illustrates how computer 1 calculates a
12 directed graph for the traded instrument L:Q, i.e., how
13 computer 1 performs step 172 of Figure ~~24~~23. This is akin to
14 producing a graph such as that shown in Fig. ~~6~~5, with arrows
15 as in Fig. ~~11~~10. The operation commences at step 191. At
16 step 192, the edge 3 set G is nulled out. At step 193,
17 computer 1 searches its records for any account A that it has
18 not yet processed. The order of selection of unprocessed
19 accounts is irrelevant. Account A is any pre-existing trading
20 (credit) relationship between two neighboring agents 2 that has
21 been previously conveyed to the operator of computer 1 in
22 writing in conjunction with these agents 2 subscribing to the
23 trading system operated by the operator of computer 1.

24
25 Step 194 asks whether there is any such unprocessed
26 account A. If "not", this process stops at step 198. If there
27 is an unprocessed account A, the process executes step 195,
28

1 where the minimum and maximum excursions for account A are
2 calculated. Step 195 is the subject of Figure ~~26-~~25. These
3 minimum and maximum excursions are defined in terms of the lot
4 instrument L, and are calculated from one or more of eight
5 possible ways of specifying input credit limits. The maximum
6 and minimum excursions are excursions from current position.
7 The input credit limits are specified as part of each account
8 A. In step 196, the set of edges G is augmented with an edge 3
9 from A's lender 2 to As borrower 2, with the capacity of the
10 edge 3 being set to the maximum excursion. L is the lot
11 instrument and Q is the quoted instrument. In step 197, the
12 set of edges G is augmented with an edge 3 from A's borrower 2
13 to As lender 2, with the capacity of the edge 3 being set to
14 the negative of the minimum excursion. The process then re-
15 executes step 193.

17 Figure ~~26-~~25 shows how computer 1 calculates the minimum
18 and maximum excursions for a single account A and a single
19 traded instrument L:Q, i.e., how computer 1 executes step 195
20 of Figure ~~26-~~25. This computation takes into account up to
21 eight different ways a guaranteeing agent 5 may specify input
22 credit limits in an account A. The operation commences at step
23 201. At step 202, the maximum excursion is set to be infinity
24 and the minimum excursion is set to be minus infinity, because
25 at this point there are no trading limits.
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1 Step 203 asks whether position limits have been defined
2 for the lot instrument. If yes, step 204 is executed. At step
3 204, the lot instrument position limits effects on the maximum
4 and minimum excursions are calculated. This is the subject of
5 Figure ~~27-26~~. At step 205, it is asked whether volume limits
6 have been specified for the lot instrument. If so, step 206 is
7 executed. At step 206, the lot limit volume limits' effects on
8 the maximum and minimum excursions are calculated. This is the
9 subject of Figure ~~29-28~~. At step 207, it is asked whether
10 position limits have been specified for the quoted instrument.
11 If so, step 208 is executed. At step 208, the quoted
12 instrument position limits' effects on the maximum and minimum
13 excursions are calculated. This is the subject of Figure
14 ~~28-27~~. At step 209, it is asked whether volume limits have
15 been specified for the quoted instrument. If so, step 210 is
16 executed. At step 210, the quoted instrument volume limits'
17 effects on the maximum and minimum excursions are calculated.
18 This is the subject of Figure ~~30-29~~. At step 211, it is asked
19 whether notional position limits have been specified. If so,
20 step 212 is executed. At step 212, the notional position
21 limits' effects on the maximum and minimum excursions are
22 calculated. This is the subject of Figure ~~31-30~~. At step 213,
23 it is asked whether notional volume limits have been specified.
24 If so, step 214 is executed. At step 214, the notional volume
25 limits' effects on the maximum and minimum excursions are
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1 calculated. This is the subject of Figure ~~32~~31. At step 215,
2 it is asked whether position limits have been specified for the
3 traded instrument L:Q. If so, step 216 is executed. At step
4 216, the traded instrument L:Q position limits' effects on the
5 maximum and minimum excursions are calculated. This is the
6 subject of Figure ~~33~~32. At step 217, it is asked whether
7 volume limits have been specified for the traded instrument
8 L:Q. If so, step 218 is executed. At step 218, the traded
9 instrument L:Q volume limits' effects on the maximum and
10 minimum excursions are calculated. This is the subject of
11 Figure ~~34~~33.
12

13 Then step 219 is executed, where the maximum excursion is
14 set to be equal to the maximum of 0 and the current value of
15 the maximum excursion. This is done because we don't want to
16 have a negative maximum excursion. At step 220, the minimum
17 excursion is set to be the minimum of 0 and the current value
18 of the minimum excursion. This is done because we do not want
19 to have a positive minimum excursion. Then, the method ends at
20 step 221.
21

22 It is important to note that the order of taking into
23 account the effects of the eight types of specified input
24 credit limits is irrelevant, because each of the eight can only
25 constrict an excursion more, not expand it. Therefore, the
26 ultimate limit is the most restrictive one. All of the eight
27
28

1 trading limits described herein are recalculated after each
2 trade affecting that limit.

3 As used herein, a "trading limit" is something calculated
4 by computer 1, and a "credit limit" is something specified by a
5 guaranteeing agent 5.

6 Conventional mathematical shortcuts can be used to speed
7 the calculations without necessarily having to repeat all the
8 method steps in all but the first time a particular method is
9 executed. All of the steps of Fig. ~~26~~25 get executed the first
10 time a method shown in Figures ~~27~~26 through ~~34~~33 is executed.

11 Figure ~~27~~26 shows how computer 1 calculates the position
12 limit for the lot instrument, i.e., how computer 1 performs
13 step 204 of Figure ~~26~~25. A position limit is a net limit in
14 the instrument being traded. The method starts at step 231.
15 At step 232, computer 1 retrieves the specified input maximum
16 position credit limit for instrument L, PMAX(L), and the
17 specified input minimum position credit limit for instrument L,
18 PMIN(L). Normally, PMIN(L) is the negative of PMAX(L), but
19 that doesn't necessarily have to be true. Also in step 232,
20 the net position, POS, is zeroed out.

21 In step 233, computer 1 looks for another unsettled flow
22 of instrument L in account A. "Another" is arbitrary. At step
23 234, it is asked whether such another unsettled flow exists.
24 If not, control passes to step 238. If the answer is "yes",
25 step 235 is executed, wherein it is asked whether the flow is
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1 to account A's borrower 2. A "flow" is a transfer of a single
2 instrument along a single edge 3. This is the same as asking
3 whether the flow is to other than a guaranteeing agent 5,
4 because the lender is the guaranteeing agent 5. If the answer
5 is yes, step 236 is executed, during which POS is augmented by
6 the flow amount, and control passes back to step 233. This
7 inner loop 233-236 constitutes calculation of the net position,
8 and is performed for each Q matching that L.

9 If the answer to the question posed in step 235 is "no",
10 step 237 is executed, wherein POS is decremented by the flow
11 amount, and control is passed back to step 233. At step 238, X
12 is set to be equal to $PMAX(L)$ minus POS, and Y is set equal to
13 $PMIN(L)$ minus POS. X is the maximum excursion from this
14 flowchart and Y is the minimum excursion from this flowchart.
15 At step 239, the maximum excursion for the traded instrument
16 L:Q is set to be equal to the minimum of the current value of
17 this maximum excursion and X; and the minimum excursion for the
18 traded instrument L:Q is set to be equal to the maximum of the
19 minimum of the current value of the minimum excursion and Y.
20 In other words, the set of maximum and minimum excursions is
21 updated based upon the results of this flowchart. The method
22 ends at step 240.

23 Figure ~~26~~27 illustrates how computer 1 calculates the
24 position limit for the quoted instrument, i.e., how computer 1
25 performs step 208 of Figure ~~26~~25. Other than the fact that Q
26

1 is substituted for L, the method described in Figure ~~28~~27 is
2 identical to that described in Figure ~~27~~,26, with one
3 exception: in step 259 (analogous to step 239 of Figure ~~27~~26),
4 we convert from the quoted instrument to the lot instrument,
5 because we want everything expressed in terms of the lot
6 instrument once we get to the higher level flowchart (Fig.
7 ~~26~~25). Therefore, in step 259, X and Y are each multiplied by
8 a "fixed rate Q:L" (exchange rate). This exchange rate is
9 fixed for a certain period of time, e.g., one hour or one day,
10 and may be different for different accounts at the same moment
11 in time.
12

13 Figure ~~29~~28 illustrates how computer 1 calculates the
14 volume limit for the lot instrument, i.e., how computer 1
15 performs step 206 of Figure ~~26~~,25. A volume limit is a gross
16 limit in the instrument being traded. The method starts at
17 step 271. In step 272, computer 1 retrieves the specified
18 input maximum permissible volume credit limit for instrument L,
19 VMAX(L); and clears a variable field VOL representing total
20 volume. In step 273, computer 1 looks for another unsettled
21 flow of instrument L in account A. "Another" is arbitrary. At
22 step 274, it is asked whether such another unsettled flow has
23 been found. If "yes", at step 275, VOL is augmented with the
24 flow amount. It doesn't matter whether the flow is in or out
25 to a particular node 2; it counts towards the volume limit the
26 same in each case.
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Control is then passed back to step 273. If the answer posed in step 274 is "no", step 276 is executed, wherein X is set equal to VMAX(L) minus VOL, and Y is set equal to minus X, because of the definition of "volume". Again, X and Y are the partial limits as calculated by this particular flowchart. Then in step 277, the maximum excursion is set equal to the minimum of the previous value of the maximum excursion and X; in the minimum excursion is set equal to the maximum of the previous value of the minimum excursion and minus X. In other words, the overall excursions are updated based upon the results of this flowchart. The method then ends at step 278.

Figure ~~30~~29 illustrates how computer 1 calculates the volume limit for the quoted instrument, i.e., how computer 1 performs step 210 of Figure ~~26~~25. Other than the fact that Q is substituted for L, the method steps of Figure ~~30~~29 are identical to those of Figure ~~29~~28, with one exception: in step 287 (analogous to step 277 of Figure ~~29~~28), X and minus X are each multiplied by "fixed rate Q:L" for the same reason that this factor was introduced in Figure ~~28~~27.

Figure ~~31~~30 illustrates how computer 1 calculates the notional position limit, i.e., how computer 1 performs step 212 of Figure ~~26~~25. The notional position limit protects the guaranteeing agent 5 against rate excursions aggregated over the positions in all of the instruments. "Notional" means we are changing the notation; the concept implies that there is a

1 conversion from one instrument to another, and that the
2 conversion is done at a certain rate that has been agreed upon.
3 The rate is set periodically, e.g., daily. This conversion
4 from one instrument to another is used to convert all values
5 into a single currency for the purpose of aggregation into a
6 single value.

7 The method commences at step 291. At step 292, computer 1
8 retrieves the maximum notional position credit limit PMAXN,
9 where N is the notional instrument, i.e, the instrument in
10 which the limit is presented. In step 292, the notional
11 position, NPOS, is also zeroed out. In step 293, computer 1
12 looks for another instrument C with flows in account A. C is
13 an index designating the instrument for which we are executing
14 the loop 293-301. The order of selecting the instruments is
15 immaterial. Step 294 asks whether such another instrument C
16 has been found. If not, control passes to step 302. If the
17 answer is yes, step 295 is executed, wherein the instrument
18 position, POS(C), is zeroed out. At step 296, computer 1 looks
19 for another unsettled flow of instrument C in account A.
20
21

22 Step 297 asks whether such another unsettled flow has been
23 found. If not, control passes to step 301. If the answer is
24 "yes", step 298 is executed, where it is asked whether the flow
25 is to account A's borrower 2. If "yes", POS(C) is augmented
26 with the flow amount at step 299. If not, POS(C) is
27 decremented by the flow amount at step 300. In either case,
28

control is returned to step 296. Note that the inner loop 296-300 is analogous to the loops in Figures ~~27~~26 and ~~28~~27. At step 301, NPOS is augmented by the absolute value of POS(C) multiplied by "fixed rate C:N", which converts to the notional instrument. The absolute value of POS(C) is used, because a negative position presents the same risk to the guaranteeing agent 5 as a positive position.

Before we describe step 302, let us define A and B, as those terms are used in step 302. Note that "A" in step 302 is not the same as "account A". A is the position of L, POS(L), multiplied by "fixed rate L:N", which converts this position to the notional instrument. B is the position of Q, POS(Q), multiplied by "fixed rate Q:N", which converts this to the notional instrument. The positions of L and Q are as calculated in the above loop 294-301; if L and Q were not subject to these notional limits, then A and B would be 0.

In step 302, computer 1 finds the minimum and maximum roots of $F(X)$, where $F(X)$ is defined in step 302. The term "root" is that of conventional mathematical literature, i.e., a value of X that makes $F(X)$ equal to 0. Let us define E to be equal to the absolute value of A plus B, plus NPOS, minus the absolute value of A, minus the absolute value of B, minus PMAXN. If E is greater than 0, then there are no roots. In that eventuality, we set the maximum excursion of the traded instrument L:Q, MAXEXC(L,Q), and the minimum excursion of the

1 traded instrument L:Q, MINEXC(L,Q), to be equal to 0. If E is
2 less than or equal to 0, the maximum root is the maximum of
3 minus A and B, minus E/2; and the minimum root is the minimum
4 of minus A and B, plus E/2. Now we are ready to go to step
5 303.

6 At step 303, the maximum excursion of the traded
7 instrument L:Q is set equal to the minimum of the previous
8 version of the maximum excursion of the traded instrument L:Q
9 and the maximum root multiplied by "fixed rate N:L", which
10 converts it to the lot instrument. Similarly, the minimum
11 excursion of the traded instrument L:Q is set equal to the
12 maximum of the previous version of the minimum excursion of the
13 traded instrument L:Q and the minimum root multiplied by the
14 same conversion factor, "fixed rate N:L". The method
15 terminates at step 304.

17 Figure ~~32~~31 illustrates how computer 1 calculates the
18 notional volume limit, i.e., how computer 1 performs step 214
19 of Figure ~~26~~25. The method starts at step 311. At step 312,
20 computer 1 retrieves the specified input maximum notional
21 volume credit limit, VMAXN. This is a limit across all
22 instruments in the account. At step 312, the total volume,
23 VOL, is also zeroed out. At step 313, computer 1 looks for
24 another unsettled flow of any instrument C in account A.
25 Again, "another" is arbitrary. At step 314, it is asked
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1 whether such another unsettled flow has been found. If "yes",
2 step 315 is executed; if "no", step 316 is executed.

3 Let R be the conversion factor "fixed rate C:N", where C
4 is the instrument that we are looping through currently. Then,
5 step 315 sets VOL to be the previous VOL plus the quantity R
6 times the flow amount. Step 313 is then entered into. At step
7 316, X is set equal to VMAXN minus VOL. Again, X is the limit
8 from just this flowchart. At step 317, the maximum excursion
9 of the traded instrument L:Q is set equal to the minimum of the
10 previous value of the maximum excursion of the traded
11 instrument L:Q and X times "fixed rate N:L", i.e., we are
12 converting from the notional instrument to the lot instrument.
13 Similarly, the minimum excursion of the traded instrument L:Q
14 is set equal to the maximum of the previous version of the
15 minimum excursion of the traded instrument L:Q and minus X
16 times the same conversion factor. The method ends at step 318.

17
18 Figure ~~33~~32 illustrates how computer 1 calculates an
19 instrument position limit, i.e., how computer 1 performs step
20 216 of Figure ~~26~~25. This type of position limit differs from
21 the previous position limit flowcharts (Figures ~~27~~26 and ~~28~~27)
22 in that the guaranteeing agent 5 is specifying that another
23 agent 2 cannot trade any more than j L for Q, rather than the
24 other agent 2 can trade no more than jL or jQ. This type of
25 input credit limit is not as common as the ones described in
26 Figures ~~27~~26 and ~~28~~27. If no agent 2 has specified this type
27
28

1 of input credit limit, this flowchart 33 does not have to be
2 executed. (Similarly, if no agent 2 has specified a certain
3 other type of input credit limit, the flowchart corresponding
4 to that credit limit does not have to be executed.) Both the L
5 and the Q have to match in order for this flowchart 33 to be
6 executed, unlike the flowcharts described in Figures ~~27~~26 and
7 ~~28~~27.

8 The method starts at step 321. At step 322, computer 1
9 looks up the specified maximum position credit limit for the
10 traded instrument L:Q, $PMAX(L,Q)$, and the specified minimum
11 position credit limit for the traded instrument L:Q, $PMIN(L,Q)$.
12 In step 322, the total position, POS, is also zeroed out. In
13 step 323, computer 1 looks for another unsettled flow pair with
14 lot instrument L, quoted instrument Q, and account A. Again,
15 "another" is arbitrary. At step 324, it is asked whether such
16 another unsettled flow pair has been found. If "no", control
17 passes to step 328. If "yes", control passes to step 325,
18 where it is asked whether the lot instrument flows to account
19 A's borrower 2. In other words, the calculation is done in
20 terms of the lot instrument to begin with, so that we do not
21 have to convert to the lot instrument at the end of the
22 calculation. If the answer to this question is "yes", step 326
23 is executed, where POS is incremented with the lot instrument
24 flow amount. Control then passes to step 323. If the answer
25 to the question posed in step 325 is "no", step 327 is
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1 executed, where POS is decremented by the lot instrument flow
2 amount. Again, control then passes to step 323. At step 328,
3 X is set equal to $PMAX(L,Q)$ minus POS, and Y is set equal to
4 $PMIN(L,Q)$ minus POS. At step 329, the maximum excursion of the
5 traded instrument L:Q is set equal to the minimum of the
6 previous version of the maximum excursion of the traded
7 instrument L:Q and X; and the minimum excursion of the traded
8 instrument L:Q is set equal to the maximum of the previous
9 value of the minimum excursion of the traded instrument L:Q and
10 Y. The method ends at step 330.

12 Figure ~~34~~33 illustrates how computer 1 calculates a traded
13 instrument volume limit, i.e., how computer 1 performs step 218
14 of Figure ~~26~~25. This method is similar to the method
15 described in Figures ~~29~~28 and ~~30~~29, except the limit is on the
16 volume traded of L for Q, not a limit on the volume of L or Q
17 individually. The method starts at step 341. In step 342,
18 computer 1 retrieves the specified maximum volume input credit
19 limit for the traded instrument L:Q, $VMAX(L,Q)$. Also in step
20 342, the total volume VOL is zeroed out. In step 343, computer
21 1 looks for another unsettled flow pair with lot instrument L,
22 quoted instrument Q, and account A. Again, "another" is
23 arbitrary.
24

25 At step 344, it is asked whether such another unsettled
26 flow pair has been found. If "no", control passes to step 346.
27 If "yes", control passes to step 345, where VOL is augmented by
28

1 the lot instrument flow amount. The calculation is done in the
2 lot instrument, so that we do not have to convert to the lot
3 instrument at the end; and it makes the calculation more
4 stable, because we don't have to worry about fluctuating rates.
5 Control is then passed to step 343. At step 346, X is set
6 equal to $V_{MAX}(L, Q)$ minus VOL. At step 347, the maximum
7 excursion of the traded instrument L:Q is set equal to the
8 minimum of the previous version of the maximum excursion of the
9 traded instrument L:Q and X. Similarly, the minimum excursion
10 of the traded instrument L:Q is set equal to the maximum of the
11 previous value of the minimum excursion of the traded
12 instrument L:Q and minus X. The method stops at step 348.

14 Figure ~~35~~34 illustrates the reporting by computer 1 of
15 single-hop trades. This method is executed after a match has
16 been made, i.e., after a bid or offer has been taken by a
17 counterparty 2. The method of Figure ~~35~~34 can be done either
18 in real time or in batch mode (i.e., combined with the
19 reporting of other trades). In Fig. ~~35~~34, L is the lot
20 instrument, Q is the quoted instrument, B is the agent 2 who is
21 buying L, S is the agent 2 who is selling L, P is the trade
22 price, F_L is the amount of L bought and sold, F_Q is P times F_L ,
23 i.e., the counter-amount in terms of instrument Q, and T is the
24 settlement date and time.

26 The method starts at step 351. At step 352, central
27 computer 1 issues an electronic deal ticket 353 to an auditor.
28

1 The auditor is a trusted third party, e.g., an accounting firm.
2 Ticket 353 has a plaintext portion and an encrypted portion.
3 The plaintext gives the ticket ID, and the time and date that
4 the ticket 353 is generated. The encrypted portion states that
5 agent B bought F_L for F_Q from agent S for settlement at T.
6 Deal ticket 353 is digitally signed by central computer 1 for
7 authentication purposes, and encrypted by central computer 1 in
8 a way that the auditor can decrypt the message but central
9 computer 1 cannot decrypt the message. This is done for
10 reasons of privacy, and can be accomplished by computer 1
11 encrypting the message using the public key of the auditor in a
12 scheme using public key cryptography.

14 At step 354, computer 1 issues an "in" flow ticket 355 to
15 buyer B and to the auditor. Flow ticket 355 contains a
16 plaintext portion and an encrypted portion. The plaintext
17 gives the ticket ID, the time and date the ticket 355 is
18 generated, and the name of agent B. The encrypted portion
19 states that you, agent B, bought F_L for F_Q from counterparty S
20 for settlement at T. Ticket 355 is digitally signed by
21 computer 1 and encrypted in such a way that it may be decrypted
22 only by agent B and by the auditor, not by computer 1. Two
23 different encryptions are done, one for agent B and one for the
24 auditor.
25

26 At step 356, computer 1 issues an "out" flow ticket 357 to
27 seller S and to the auditor. Out flow ticket 357 contains a
28

1 plaintext portion and an encrypted portion. The plaintext
2 gives the ticket ID, the time and date of issuance, and the
3 name of agent S. The encrypted portion states that you, agent
4 S, sold F_L for F_0 to counterparty B for settlement at T.
5 Ticket 357 is digitally signed by computer 1 and encrypted only
6 to agent S and to the auditor, not to computer 1. Two
7 different encryptions are used, one to agent S and one to the
8 auditor.

9 Tickets 353, 355, and 357 can include the digital identity
10 of the individual within the agent 2 whose smartcard was
11 plugged into the agent's computer when the transaction was
12 made. The method ends at step 358.

13 Figure ~~36~~35 illustrates how computer 1 electronically
14 reports a multi-hop deal. This method is performed after the
15 match has been made and can be done either in real time or in
16 batch mode. Agents B and S do not know each other, as they
17 know the identities of just their nearest neighboring agents 2.
18 The notation for this flowchart is identical to that for Figure
19 35, except that B is the ultimate buyer of L and S is the
20 ultimate seller of L.

21 The method begins at step 361. At step 362, computer 1
22 issues deal ticket 363 to the auditor. Ticket 363 contains a
23 plaintext portion and an encrypted portion. Ticket 363 is
24 digitally signed by computer 1 and encrypted only to the
25 auditor. The encrypted portion states that agent B bought F_L
26
27
28

1 for F_0 from agent S for settlement at T, and that the deal was
2 fulfilled by multiple direct trades in D, the directed deal
3 fulfillment graph, i.e., the type of graph that is illustrated
4 in Figure ~~11~~10. In other words, the auditor knows every agent
5 2 in the chain.

6 At step 364, computer 1 looks for the next unprocessed
7 agent V in graph D. Again, "next" is arbitrary. At step 365,
8 it is asked whether such an unprocessed agent V has been found.
9 If not, the method stops at step 366. If the answer is "yes",
10 node loop 370 is entered into. For agent V, this node loop
11 examines the set E_V of directed edges 3 in D which have agent V
12 as either a source or destination. Each edge 3 has an amount F
13 that is greater than zero and less than or equal to F_L . Note
14 that this verification process is for illustration only; there
15 would not be a match if these constraints were not satisfied.
16 At step 367, it is asked whether agent V is the ultimate buyer
17 B of the deal. If "no", control is passed to step 368. If
18 "yes", control is passed to step 371.

21 At step 368, it is asked whether agent V is the ultimate
22 seller S of the deal. If "no", control is passed to step 369.
23 If "yes", control is passed to step 372. At step 369, computer
24 1 concludes that agent V is an incidental participant in the
25 deal, i.e., a middleman 5. Control is then passed to step 373,
26 which verifies that the sum of the edge 3 amounts having agent
27 V as a source equals the sum of the edge amounts 3 having agent
28

1 V as a destination. Sums are used because that agent 5 could
2 have several edges 3 in and out. Therefore, it is known that
3 agent V has no net market position change. Control is then
4 passed to step 376. At step 372, it is verified that agent V
5 is the source node 2 (as opposed to the destination node) of
6 all edges 3 in E_V . In step 375, it is verified that edge 3
7 amounts in E_V sum to F_L , the net amount sold. Control is then
8 passed to step 376.

9 In step 371, it is verified that agent V is the
10 destination node 2 (as opposed to the source node) of all edges
11 3 in E_V . At step 374, it is verified that edge 3 amounts in E_V
12 sum to F_L , the net amount bought. Control is then passed to
13 step 376, where computer 1 looks for the next unprocessed edge
14 in E_V corresponding to account A. Steps 376-382 constitute an
15 edge loop. Account A is any account held by or extended to
16 counterparty X. Counterparty X is the counterparty 2 to agent
17 V for that edge 3. The edge 3 has to have some amount F, where
18 F is greater than 0 and less than or equal to F_L , and an
19 implicit counter-amount F times P; otherwise, there would be no
20 way to clear the trade. Again, "next" in step 376 is
21 arbitrary. Control is then passed to step 382.

22 At step 382, it is asked whether such a next unprocessed
23 edge 3 has been found. If not, control is passed to step 364.
24 If "yes", control is passed to step 381, where it is asked
25 whether agent V is the destination node 2 for this edge 3. If
26
27
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1 "yes", then step 380 is executed. If "no", then by definition,
2 agent V is the source node 2 for this edge 3, and step 379 is
3 executed. Control is passed to step 376 after either of step
4 379 or 380 is executed.

5 At step 380, computer 1 reports an "in" flow ticket 377 to
6 agent V, because the lot currency is flowing in to agent V.
7 Flow ticket 377 contains a plaintext portion and an encrypted
8 portion. The plaintext includes the ticket ID, the time and
9 date of issuance, and the name of agent V. The encrypted
10 portion states that you, agent V, bought F of L for F times P
11 of Q from counterparty X for settlement at T. In this case,
12 counterparty X is just the immediate neighbor 2 to agent V,
13 preserving anonymity. Ticket 377 is digitally signed by
14 computer 1 and encrypted by computer 1 only to agent V and to
15 the auditor, not to computer 1. Two encryptions are performed,
16 one to agent V and one to the auditor.
17

18 At step 379, computer 1 generates an "out" flow ticket 378
19 to agent V. Ticket 378 contains a plaintext portion and an
20 encrypted portion. The plaintext includes the ticket ID, the
21 time and date of issuance, and the name of agent V. The
22 encrypted portion states that you, agent V, sold F of L for F
23 times P of Q to counterparty X for settlement at T. Again,
24 counterparty X is just the immediate neighbor 2 to agent V,
25 preserving anonymity. Flow ticket 378 is digitally signed by
26 computer 1 and encrypted by computer 1 only to agent V and to
27
28

1 the auditor, not to computer 1. Two encryptions are performed,
2 one to agent V and one to the auditor.

3 Tickets 363, 377, and 378 can include the digital identity
4 of the individual within agent 2 whose smartcard was plugged
5 into the agent's terminal when the transaction was made.

6 The above description is included to illustrate the
7 operation of the preferred embodiments and is not meant to
8 limit the scope of the invention. The scope of the invention
9 is to be limited only by the following claims. From the above
10 discussion, many variations will be apparent to one skilled in
11 the art that would yet be encompassed by the spirit and scope
12 of the present invention.
13

14 What is claimed is:
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